BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 06007

SUBJECT: Feasibility of Hybrid Lunar Missions to Hadley, Copernicus, Davy, Marius Hills and Descartes from Early 1971 through 1974 - Case 310

DATE: June 2, 1970

FROM: D. R. Anselmo
R. A. Bass

ABSTRACT

Hybrid missions to Descartes flown with a control-weight spacecraft are possible throughout the J-mission time period. Missions to Marius Hills, Davy, Hadley and Copernicus with a control-weight spacecraft are not feasible during some of the winter months. The feasibility of a mission is determined by a comparison of performance requirements with capability for both the service propulsion system and the launch vehicle. With few exceptions, infeasible missions exceed the capabilities of both the SPS and launch vehicle.

In addition to the control weight spacecraft, a heavier model was considered which includes an allowance for growth and results in a reduction in opportunities for Marius Hills, Hadley, Davy and Copernicus. Descartes remains accessible throughout the period despite the increased spacecraft weight.

All missions considered meet the DPS abort requirement on the translunar trajectory and land on the moon at a sun elevation between 5 and 14 degrees as well as satisfying the other J-mission objectives such as a 54-hour lunar surface stay and 36 lunar orbits between LM ascent and TEI.

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MEMORANDUM FOR FILE

Mission Planning for the J-mission series of four lunar landing missions requires consideration of possible missions from the summer of 1971 through the end of 1974 because of the intercalary SKYLAB program and to provide flexibility to meet potential landing site assignment changes. Performance requirements for each mission opportunity determine the feasibility of a potential schedule. Missions requiring the minimum SPS propellant were determined for each monthly launch opportunity throughout the period of interest.

Mission Assumptions

The assumptions made in optimizing the mission are detailed in the Appendix. These assumptions comply with the current objectives for the J-mission series. Two weight models were considered: the control weight spacecraft and a growth weight spacecraft (References 1 and 2). The two weight models are given in the Appendix.

The baseline launch vehicle used can inject 106,100 pounds from a 90 nautical mile earth orbit to a translunar trajectory with an energy of -8.05×10^6 ft^2/sec^2 and maintain a flight geometry reserve of 32.8 ft/sec. Launch vehicle injection capabilities for specific opportunities include the effect of translunar energies that differ from -8.05×10^6 ft^2/sec^2 and the seasonal effects of wind and temperature at launch.

Non-free return trajectories, which were constrained to be within the DPS abort ΔV capability to return to a free return trajectory, were employed. A ΔV of 45 feet/sec was budgeted for the hybrid maneuver in determining the propellant requirements for each mission opportunity. Experience has shown that this method for generating hybrid trajectory performance requirements is accurate and results in a significant savings in required computation time.

Recently MSC has proposed relaxation of the requirement for translunar injection on a nominally free return trajectory and specifying only that the trajectory be abortable to a free return with an RCS maneuver up to five hours after injection. This relaxed free return profile proposal eliminated the hybrid maneuver. The injected weight requirements presented in this memorandum would be reduced by 450 lbs. for the relaxed free return profile.

The injected weight requirement for a specific opportunity is derived by first determining the propellant required to accomplish the required propulsive maneuvers with a particular weight model. The required propellant is added to the inert weight of the CSM, the LM total weight and the SLA weight to arrive at the injected weight requirement. If the propellant required exceeds the tank capacity of the SM, the mission is not feasible. In addiiton, if the required injected weight exceeds the launch vehicle capability for that opportunity, the mission is infeasible.

Results

The injected weight requirements are compared to both launch vehicle capabilities and the spacecraft weight at injection with full SPS propellant tanks in Figures 1 through 4.

Two spacecraft limits are shown, one for each weight model with full SPS propellant tanks. The vertical bars indicate the range of injected weight requirements for both weight models, the lower value corresponding to the control weight model, the upper for the growth weight model. The shaded areas are shown to emphasize the time dependence of the performance requirements. The data for Descartes is not included because it is accessible during every month with both weight models. Feasible launch opportunities for all five sites are summarized in Figure 5.

In some cases, acceptable opportunities are shown for months that require propellant exceeding the tank capacity of the vehicle. In these cases, an early return to earth from lunar orbit in the event of a LM rescue was investigated and found to result in a feasible mission. The opportunities designated by a small triangle indicate that a mission may be flown if additional launch vehicle capability is made available, possibly by limiting the allowable launch azimuth range. In some cases both early return and launch vehicle capability improvement are necessary to produce feasible missions, for example, the control weight configuration for a November 1971 mission to Copernicus.

DR Anselmo

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RA Bass

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Attachments

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REFERENCES

1. "Control Weights for Apollo 16 and Subsequent," R. A. Petrone/MA, Letter to MSC and MSFC, January 14, 1970.

2. MSC Presentation material used at the March 6, 1970 ASSB Meeting.

APPENDIX

MISSION DESIGN CONSTRAINTS, WEIGHT MODEL AND MISSION INDEPENDENT ΔV BUDGET

1. Mission Design Constraints

- Only Pacific translunar injections are considered.
- Launch azimuth = 72 degrees.
- 40 HR $\leq$ translunar flight time $\leq$ 110 HR.
- 40 NM $\leq$ perilune altitude of incoming hyperbola $\leq$ 60 NM.
- A non-free return translunar trajectory is used. This type yields nearly the same LOI ΔV requirements as a hybrid trajectory and 45 fps has been budgeted to cover the hybrid maneuver requirements.
- A DPS abort of less than 1980 fps is possible eight hours after passing perilune on the translunar trajectory.
- A 60 NM lunar parking orbit is employed.
- The time in orbit from lunar orbit insertion to SPS descent orbit insertion (DOI) is 24 hours.
- The CSM takes the LM down to an altitude of 50,000 ft. at which point the LM begins its descent.
- Sun elevation at landing is constrained to be between 5 and 14 degrees.
- The lunar surface stay time is 54 hours.
- The time in lunar orbit from CSM-LM rendezvous to trans-earth injection is approximately 72 hours for the nominal, early return occurs after eight hours.
- 45 HR $\leq$ transearth flight time $\leq$ 112 HR.
- The return geographic inclination is less than 40 degrees.
- $-35° \leq$ earth landing latitude $\leq 35°$.
- $-170° \leq$ earth landing longitude $\leq -150°$ (Pacific zone).
- The maximum mission duration is 16 days.

MISSION INDEPENDENT ΔV'S AND WEIGHT MODEL

EVENT

ΔV (FPS)	---	HYBRID MANEUVER 45	TRANSLUNAR MIDCOURSE 33	LOI PLUS *C.C-80 DOI-75	---	CIRCULARIZATION 75	CSM PLANE CHANGE	LM RESCUE	TEI + *C.C-90
WEIGHT DROP (LBS)	149	118	219	64	610 + LM	169	330	299	---

		CONTROL WEIGHTS	GROWTH WEIGHTS
FUEL USABLE	=	39,410	39,410
CSM INERT	=	26,940	27,640
SLA	=	4,150	4,100
LM	=	36,000	36,331
INJECTED WEIGHT	=	106,500	107,481

SPS ISP = 313.9

*CONIC CALIBRATION

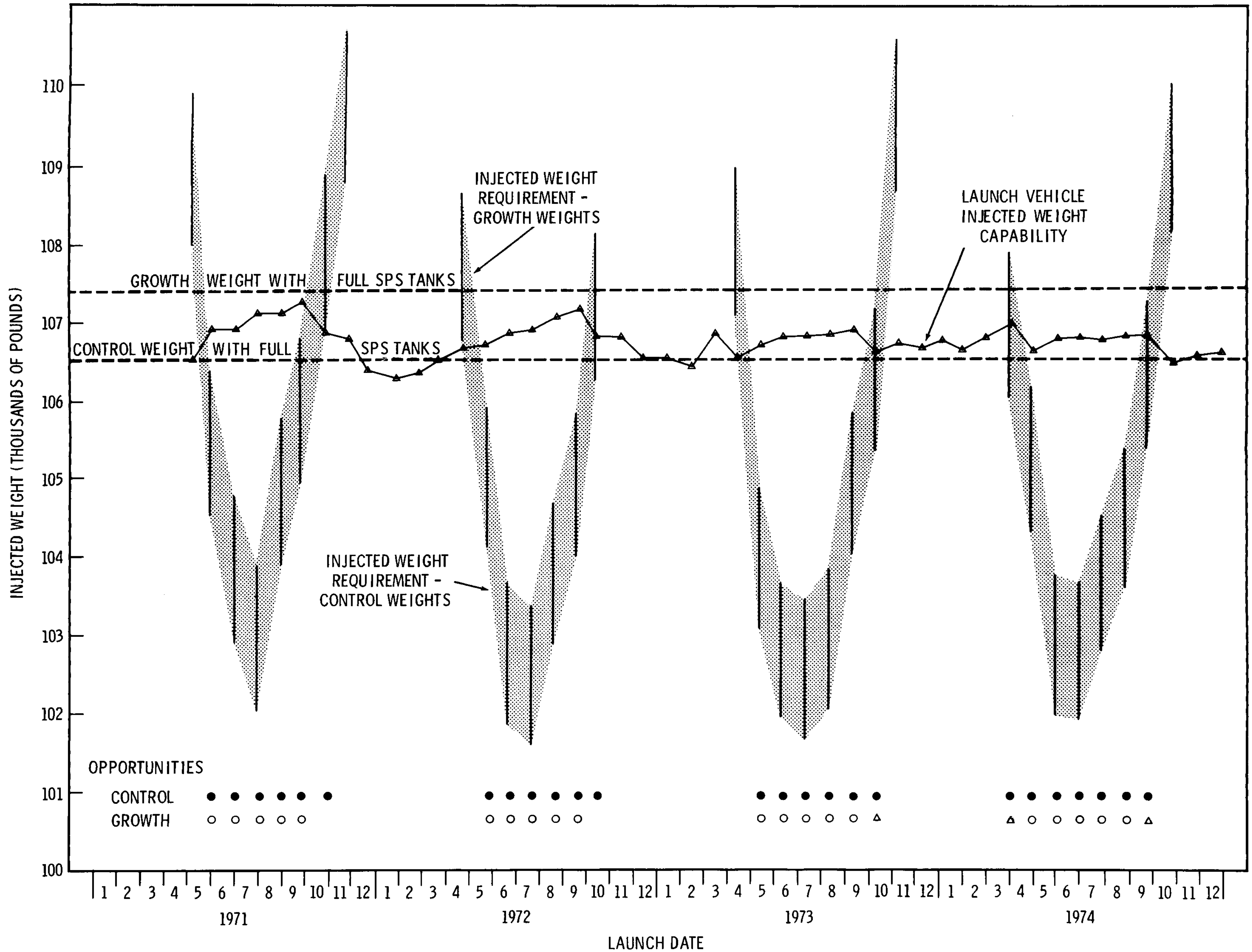


FIGURE 1 - J-MISSION OPPORTUNITIES TO MARIUS HILLS

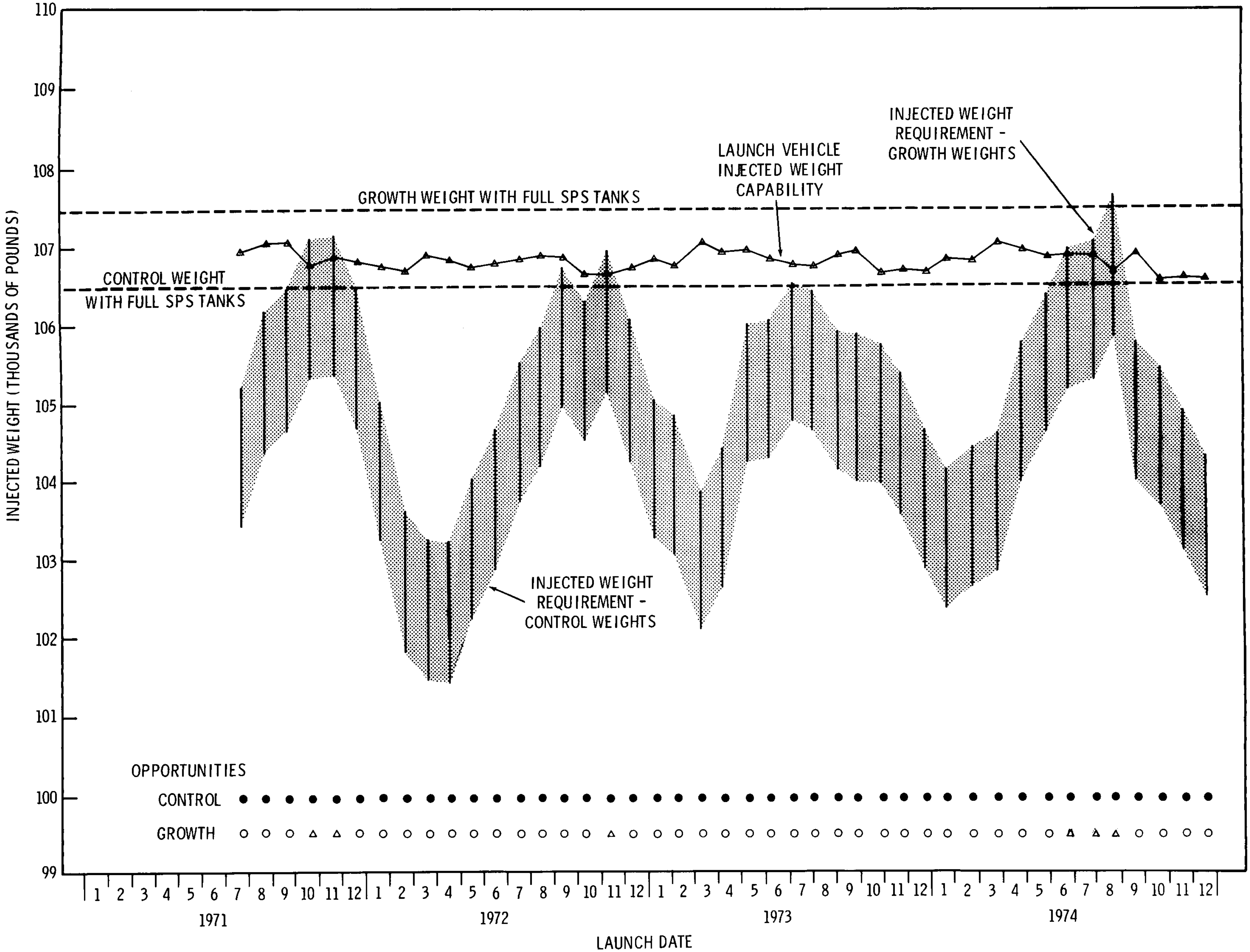


FIGURE 2 - J-MISSION OPPORTUNITIES TO DAVY RILLE

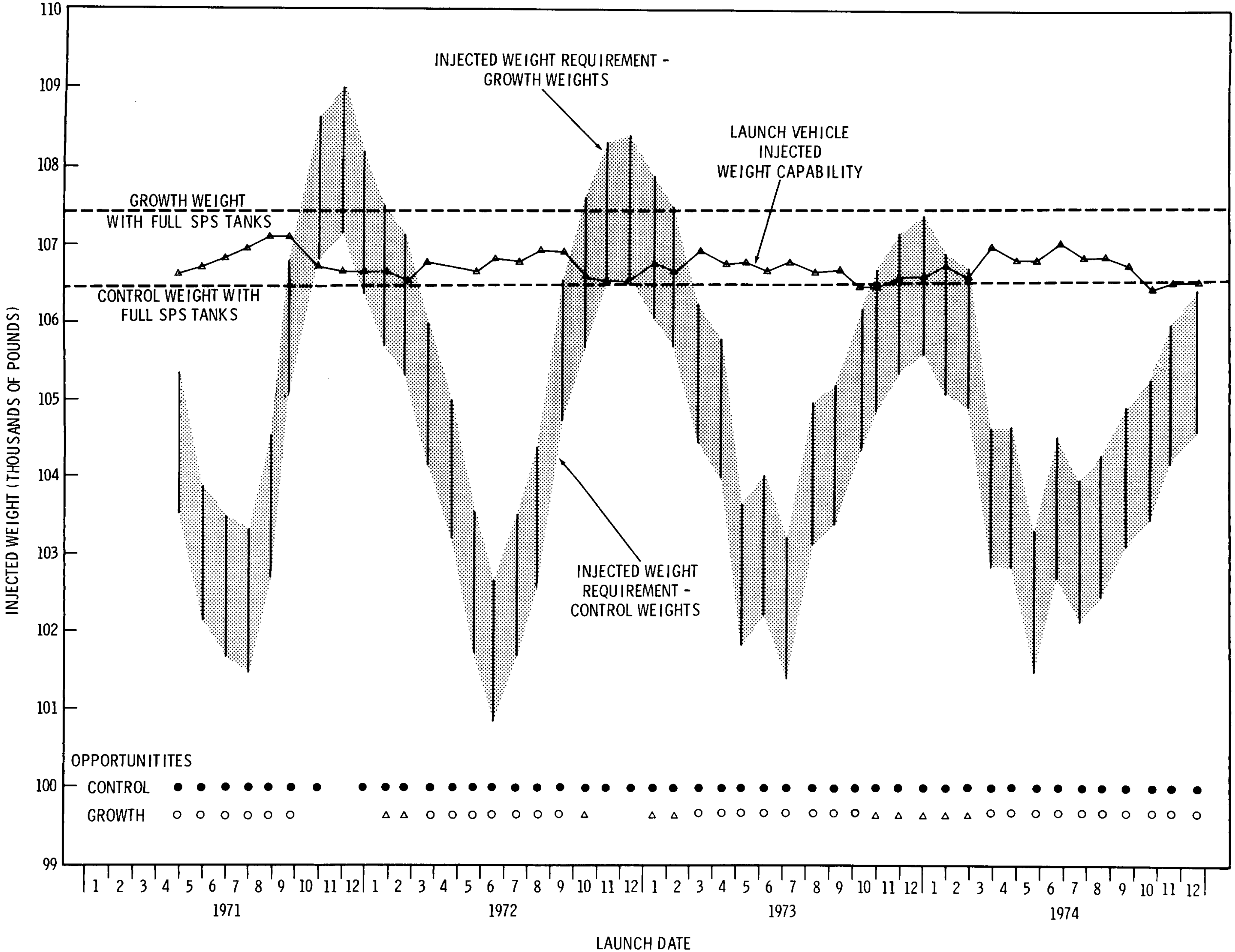


FIGURE 3 - J-MISSION OPPORTUNITIES TO COPERNICUS

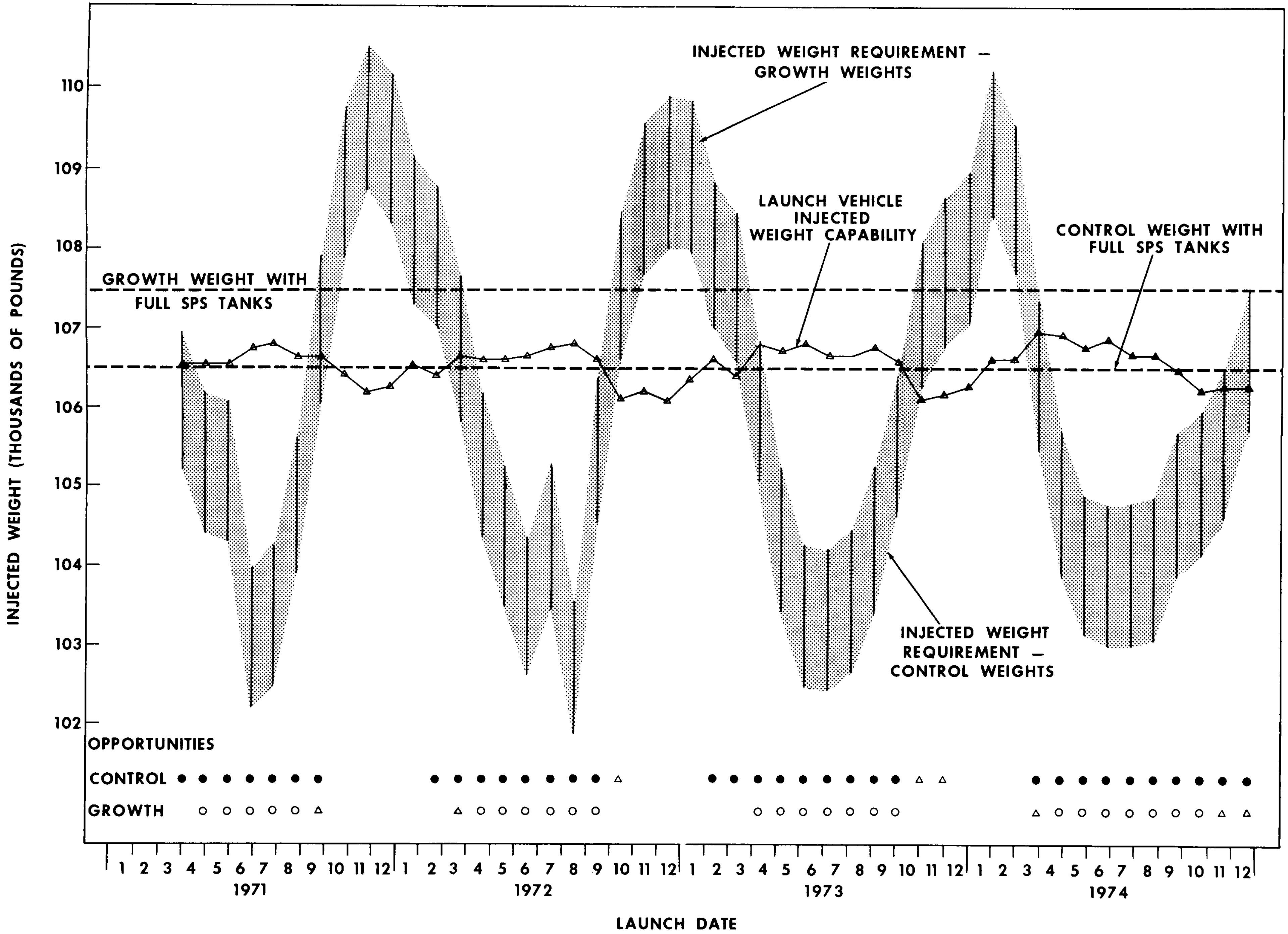
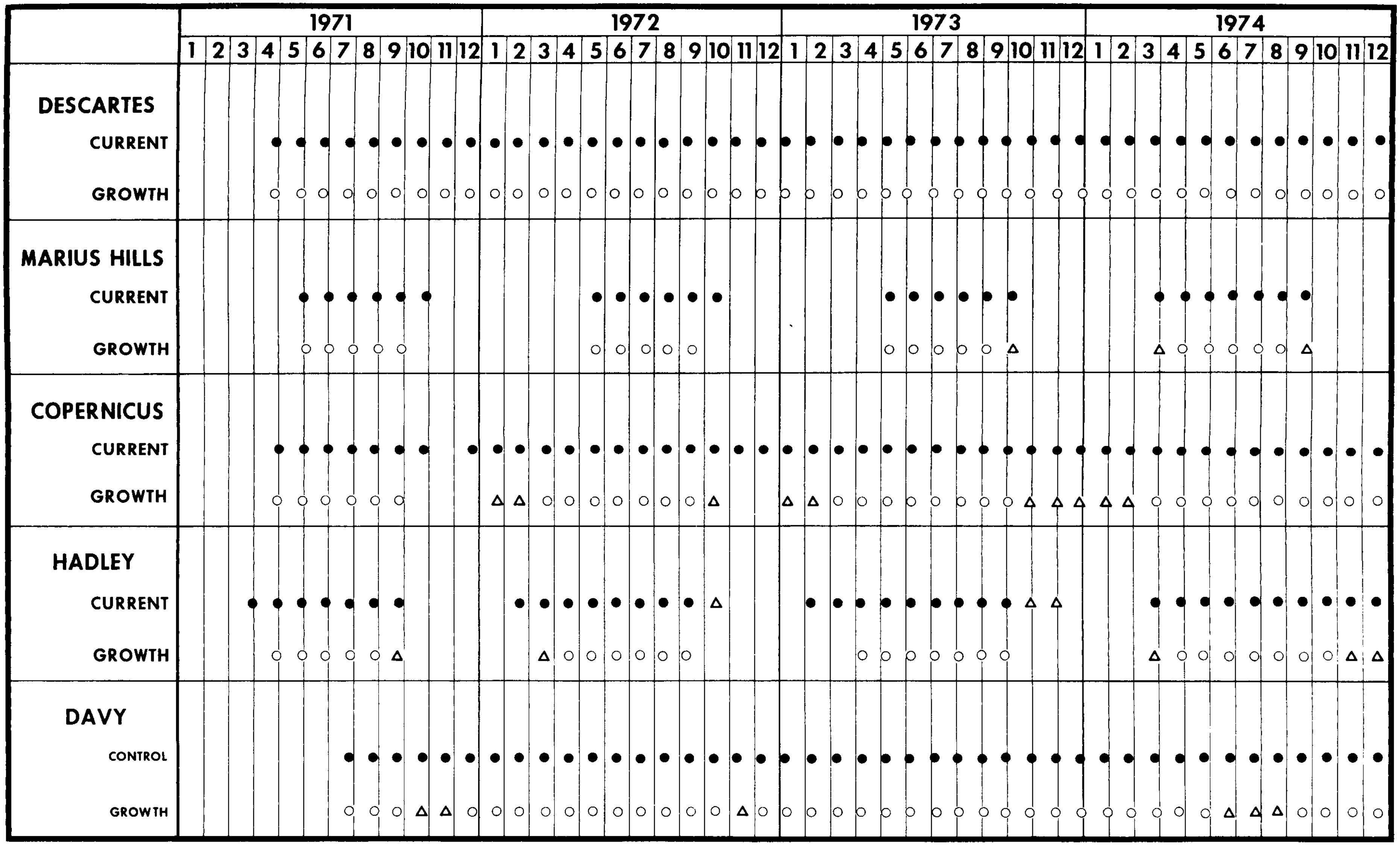


FIGURE 4 - J-MISSION OPPORTUNITIES TO HADLEY



△ LAUNCH VEHICLE LIMITED
CAPABILITY ASSUMED MISSION SPECIFIC
ENERGY, 90 NMI PARKING ORBIT, AND
WIND AND TEMPERATURE EFFECTS

FIGURE 5 - SUMMARY OF J-MISSION OPPORTUNITIES